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Landslide susceptibility in the Zab Basin, northwest of Iran

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Abstract

Landslides cause damages and harms to human lives. Proper analysis and suitable modeling of these dangers may reduce relative losses. It even prevents mass movements. The Zab river basin is susceptible to landslide. To evaluate the landslide risks in the study area, analytical hierarchy process (AHP) method and geographical information systems (GIS) as well as local data were used. The local data includes: slope, slope aspect, distance to road, distance to drainage network, land use and land cover, geological factors, geomorphologic characteristics and climatic condition of area. The use of AHP model resulted in providing a real country image indicating initial susceptibility to the landslide. Based on findings southern basins are most susceptible to landslide.

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1. Introduction

Identifying susceptible areas to landslide helps humans via prospective planning, to reduce risks or it might ever prevent risks. Analysis and distinction of these susceptible lands involves precise data and the use of a suitable modeling pattern. Modeling has been carried out using quantitative and qualitative methods such as weighted overlay, AHP, neural networks, fuzzy logic, statistical model, multivariable analysis and logistic regression [1, 2, 3, 4, 5, 6, 7]. Qualitative methods rely upon expertise reports. Every relative layer is classified and hence every factor is exactly weighted. Analytical hierarchy process (AHP) and weighted linear combination (WLC) are two proper methods [8, 9]. AHP along with GIS are powerful instruments to inspect criteria in modeling process. In this study analytical hierarchy process (AHP) along with GIS data were used to specify distinct susceptible landslide areas. The acquired data are useful for prospective planning and programming.

2. Geographical position

The study area is located in the southwest mountainsides of West-Azerbaijan province along the Zab river

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basin in Sardasht between the latitudes of (36° 8' 25")N and (36° 26' 27")N and the longitudes of (45° 21' 21")E and (45° 40' 44") E (Fig. 1).

The major part of the study area is located in the Sanandaj- Sirjan zone and its east and eastern north parts locate in the Mahabad- Khoy zone. This zone is quite susceptible to landslide due to its climatic conditions, geology, geomorphologic characteristics and human activities.

In aspect of tectonic since the region is located in major Zagros thrust direction and faults are the main causes of pit formation. The region morphology strongly affected by tectonic forces [10].

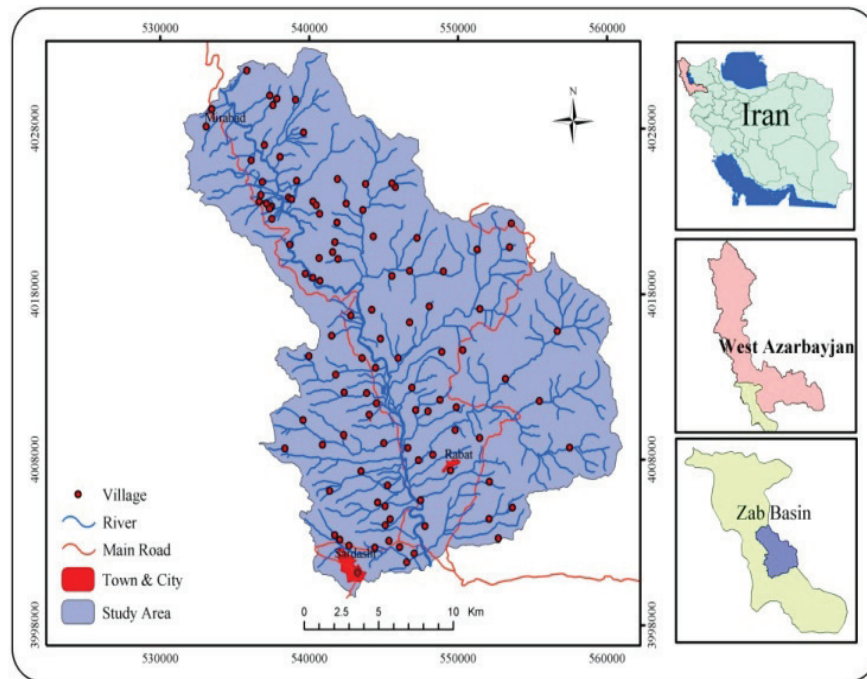


Fig. 1: Position of the study area and landslide distribution (Source: Author generated).

3. Materials and Methods

3.1. Modeling using Analytical hierarchy process (AHP)

Multiple criteria analysis (MCA) techniques are effective tools to survey complex phenomenon and extols programming. Combination of the two techniques, MCA (Multiple Criteria Analysis) and GIS, makes a technique referred to as spatial decision support system (SDSS). It is used generally to investigate location problems [11]. In Analytical hierarchy process (AHP) all criteria and factors are doubled up and are compared and result are registered in a weighting index matrix. There is nine scales ranging from 1 to 9 that gradually show priority factors [12]. One means equal values while 9 means the maximum priority (Table 1).

Table 1: Pair-wise comparison scale for AHP preferences - Source: [13]

9	8	7	6	5	4	3	2	1	Numerical rating
Extremely preferred	Very strongly to extremely	Very strongly preferred	Strongly to very strongly	Strongly preferred	Moderately to strongly	Moderately preferred	Equally to moderately	Equally preferred	Verbal judgments of preferences

All priority factors are then elicited and hence are arranged in a matrix. Double factors comparison may lead to some inconsistency. To prevent such an inconsistency, Saaty in 1977 suggested a numeric index to

control the comparison consistency. It is called consistency ratio. Consistency index (CI) divided by root means consistency index (RI) makes consistency ratio. Table 2 shows (RI) values [12].

Table 2: Values of RI - Source: [12].

n	2	3	4	5	6	7	8	>8
RI	0	0.52	0.9	1.12	1.24	1.32	1.41	1.45

3.2. Providing data

Field observations and GPS data are determined for the immensity and distribution of landslides determined (Fig. 1). Many researchers have suggested using geological and geomorphologic parameters to specify susceptible landslide areas, such as geology data, slope, slope aspect, land use, land coverage, drainage networks and main road distance, and fault distances [3, 4, 14, 15, 16, 17, 7, 18]. In this study all the above factors were used to provide different layers.

3.3. Geology

Main lithologic units consist of instable homogenous phyllite, sustainable andesite, marble and crystalline limestone, and quaternary deposits [19].

The most sensitive units to landslide are phyllite, slate, shale, and Mila formation [20]. Therefore, the geologic map was provided by considering the unit's susceptibility.

3.4. Slope

Slope maps in accordance to our aim were classified. The result shows the majority of landslides have happened on slopes with the slope angles less than 30 degrees.

3.5. Slope aspect

The slope aspect is one of the most effective factors in landslide [21, 22, 16, 23, 6, 18]. This study elicited four main geographical directions and flat areas. The number (-1) shows flat areas, north has the angles (0-45, 315-360), East (45-135), South (135-225), West (225-315).

3.6. Distance to drainage network

Although the impact of every drainage network should be monitored by land usage for study area retention buffers were provided at the distances of 0-50, 50-100, 100-150, 150-200 meters, and more. Each of them was finally taken into account observing their roles. Classifications order and buffering drainage maps are provided.

3.7. Distance to road

To investigate the roads buffers were provided. The relative distances are 0-25, 25-50, 50-100, 100-125 meters, and more (Table 3). The impact of every buffer in landslide was evaluated.

3.8. Distance to faults

The fault lines were elicited from geologic maps and afterwards observing their role and fault distances and their impacts on landslide buffering executed. Fault line distances map was provided using buffer modeling at 0-100, 100-200, 200-300, 300-400 meters and more.

3.9. Land Use

To provide the land use maps maximum likelihood classification method along with ETM data, 2002, previous maps of land use, (accuracy of 90) and Kappa index 0.8 were elicited. The most important land uses are barren lands, stone field, pastures (grade 1and2), dry farms, grove land and ordinary farms. Since above land uses control or intensify landslide, a particular weight was dedicated to each of them.

4. Results and Discussion

In consistency matrix main diameter value is 1 and the elements of lower triangle are inverted at higher triangle elements. ($a_{ji} = 1/a_{ij}$). a_{ji} is the ratio of (A priority to B priority) [24]. After arranging consistency matrix the suggested equality (Table 3). $a_{ij} \cdot a_{jk} = a_{ik}$ justifies to matrix elements.

Table 3: Consistency matrix.

Distance to road	Aspect	Distance to drainage	Distance to fault	Land use	Geology	Slope	Factor
7	4	3	1	1	1/3	1	Slope
7	5	4	3	2	1	3	Geology
6	4	3	2	1	1/2	1	Land use
5	4	3	1	1/2	1/3	1	Distance to fault
4	2	1	1/3	1/4	1/4	1/3	Distance to drainage
3	1	1/2	1/4	1/4	1/5	1/4	Aspect
1	1/3	1/4	1/5	1/6	1/7	1/7	Distance to road

After providing priority matrix and double factors mutual relationship and using Matlab7 eigen value and eigen vectors calculated. The largest eigen value equals to 7.2622 and eigen vector is the result of it (Table 4).

Table 4: Eigen vectors related to largest eigen values

Distance to road	Aspect	Distance to drainage	Distance to fault	Land use	Geology	Slope	Factor
0.1589	0.2938	0.4341	0.8775	1.1438	1.9542	1	Eigen vectors
Consistency ratio(CR)=0							

Considering relation, the consistency ratio (CR) equals 0 all components of eigen vector were added up and after substitution values in this equation, the final value was obtained (Table 5).

Table 5: Final weight of effective factors in landslide evaluation

Factor	Slope	Geology	Landuse	Distance to fault	Distance to drainage	Aspect	Distance to road
Weight of factor	0.1706	0.3334	0.1951	0.1497	0.0741	0.0501	0.0271

After weighting each factor one has to multiply the resulting weights by each layer value. Using this equation, the final was determined [25].

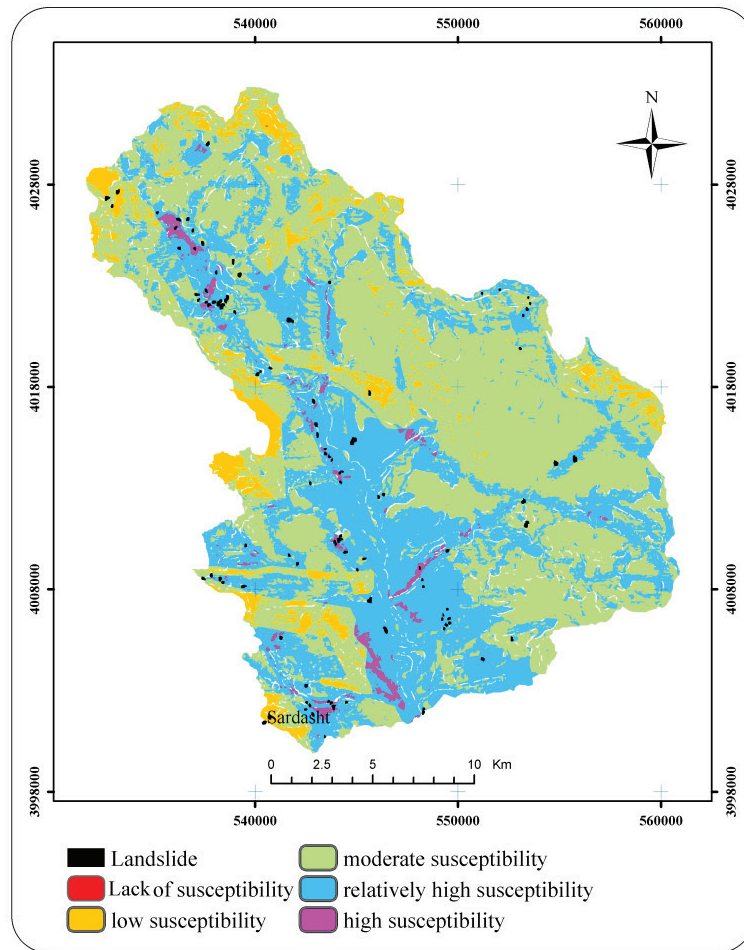


Fig. 2: Final modeling map of sensitive areas to land slide (Source: Author generated)

5. Conclusion

After the final analysis using AHP model as illustrated in Fig. 2 in the study area, no land without landslide risk was observed (Fig. 1). Major parts of the area were classified as high risk and relative high risk to landslide. Therefore, the study area is sensitive to landslide. More than 90 percent of landslides have happened in two classes, high risk and relative high risk. This agrees with the real world condition.

The results show that the AHP is a suitable study model. In addition, since AHP is based on mutual comparison, hence the researcher would be able to make better decisions for the most modeling study.

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